(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 498 281 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **92101414.8**

(51) Int. Cl.[5]: **A61B 5/0285**

(22) Date of filing: **29.01.92**

(30) Priority: **31.01.91 JP 31889/91**

(43) Date of publication of application: **12.08.92 Bulletin 92/33**

(84) Designated Contracting States: **AT BE CH DE DK ES FR GB GR IT LI LU MC NL PT SE**

(71) Applicant: **Sankyo Company Limited**
5-1 Nihonbashi Honcho 3-chome Chuo-ku
Tokyo(JP)

(72) Inventor: **Takashashi, Masaaki, c/o Biological Research Lab.**
SANKYO COMPANY, LIMITED, 2-58, Hiromachi 1-chome
Shinagawa-ku, Tokyo 140(JP)
Inventor: **Nishimura, Masatoshi, c/o Biological Research Lab.**
SANKYO COMPANY, LIMITED, 2-58, Hiromachi 1-chome
Shinagawa-ku, Tokyo 140(JP)
Inventor: **Nakatsubo, Nobuaki, c/o Biological Research Lab.**
SANKYO COMPANY, LIMITED, 2-58, Hiromachi 1-chome
Shinagawa-ku, Tokyo 140(JP)

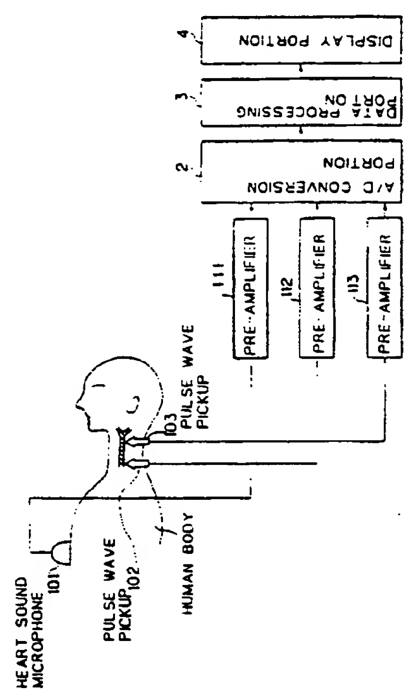
(74) Representative: **Cohausz & Florack Patentanwälte**
Postfach 14 01 61 Schumannstrasse 97
W-4000 Düsseldorf 1(DE)

(54) **Measurement of transmission velocity of pulse wave.**

(57) An apparatus for measuring a transmission velocity of a pulse wave includes a sensor 1 for sensing heart sounds, and pulse wave signals at the upstream and downstream side of a blood flow, an analog to digital conversion unit 2, a data processing unit 3, and a display unit 4.

The data processing unit 3 includes a first processor for detecting the first heat sound and generating a marker signal, second and third processors for transforming the received signals for a display thereof, a fourth processor responsive to the signals from the first, second, and third processors for detecting the marker signal and obtaining predetermined data from the data received, a fifth processor for receiving signals from the second and third processors and temporarily storing the received signals, a sixth processor for receiving signals from the fourth processor and measuring the transmission time of the pulse wave to derive the transmission velocity of the pulse wave, and a seventh processor for receiving the signal from the sixth processor and transforming the received signal for a display thereof.

Fig. 2



EP 0 498 281 A1

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus and a method of measuring the transmission velocity of a pulse wave. The method and apparatus according to the present invention are used for detecting the transmission velocity of a pulse wave in relation to the detection of the blood pressure and the elasticity of the tube wall of the artery of a human being.

2. Description of the Related Arts

In a report based on an investigation into the relationship between the degree of sclerosis of an artery and the pulse wave velocity (PWV), it was assumed that C_0 is the value of the pulse wave velocity, V is the volume of the artery, P is the internal pressure of the artery, ρ is the density of the blood (regularly 1.055 g/cm^3), and V dP/dV is the bulk modulus (volumetric elasticity), the value of C_0 is represented by the formula

$$Co = \sqrt{(V/\rho)\cdot(dP/dV)}.$$

As a result it was found that, if the density of the blood is constant, the harder the tube wall of the artery, the higher the pulse wave velocity.

Also, it is known that the pulse wave velocity (PWV) in the aorta can be calculated based on detections of the pulse wave in the carotid artery, the pulse wave in the femoral artery, and the heart sound, using the formula $PWV = 1.3L/(T + T_c)$. In this equation, L represents the straight distance from the valve opening of the aorta to the femoral artery, T the time difference between the rising point of the pulse wave in the carotid artery and the rising point of the pulse wave in the femoral artery, and T_c the time difference between the generation of the second sound, i.e., the sound of the closing of the aortic valve, of the heart sounds to the generation of the dip of the pulse wave, which is generated when the aortic valve is closed, in the carotid artery. Accordingly, "$T + T_c$" is the time of a transmission of the pulse wave from the opening of the aortic valve to the femoral artery. The coefficient "1.3" is the correction coefficient of the actual length of the artery.

Recently, a demand has arisen for a precise measurement of the PWV over a relatively short distance, as the degree of the sclerosis of the tube wall of an artery in a relatively localized range can be detected by such a precise measurement of the PWV over a relatively short distance. The detection of the localized existence of the sclerosis in the artery system, in association with the detection of the sclerosis in the entire artery system, is useful for the medical diagnosis and treatment of the vascular diseases accompanying sclerosis of the artery.

Since the carotid artery is located at the entrance of the cerebral blood vessel system, the degree of sclerosis of the tube wall of the carotid artery is considered to be as medically important as the heart artery system.

To achieve a precise measurement of the PWV over a relatively short distance, a measurement with a high time resolution is needed, since a very short transmission time on the order of milli-seconds through tens of milli-seconds of the PWV is estimated as the transmission time of the PWV over a short distance on the order of 5 cm.

In a prior art method of measuring the PWV, in which the PWV is obtained from a measurement of the time difference between 1/10 points or 1/5 points of the amplitudes of the rising parts of two pulse waves having a relatively stable pulse waveform, a problem arises in that the time difference is measured for only a single point, and if noise components are superposed on the pulse wave signal, the amount of error in the time measurement is increased. Such an error cannot be neglected, particularly in the measurement of the PWV over a short distance on the order of 5 cm.

In another prior art method of measuring the PWV, in which the waveforms of the rising parts of two pulse waves are overlapped by using an analog delay element and the delay time therebetween is measured, a problem arises in that the process of the decision based on the overlap of the waveforms is carried out only by a visual fine adjustment of an oscilloscope by the operator, an automatic measurement of PWV for each heart beat cannot be made, only an averaged value is measured because the pulse wave signals for several heart beats are required for the overlapping of the waveforms, and the dynamic response characteristic for a load test, such as the test of an increase in pressure under cold temperature conditions, cannot be detected.

To obtain information on the background of the invention, refer to an article by F. J. Callaghan et al., "Relationship Between Pulse-Wave Velocity and Arterial Elasticity", Medical & Biological Engineering & Computing, May 1986, Pages 248 to 254.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved apparatus and method of measuring the transmission velocity of a pulse wave, in which the measurement of the transmission velocity of the pulse wave over a relatively short distance can

be carried out with a high precision, a real time measurement of the transmission velocity of the pulse wave in synchronization with the heart beat becomes possible, and an output of the result of an automatic measurement of the transmission velocity of the pulse wave, with a high precision, becomes possible.

According to the present invention, there is provided an apparatus for measuring a transmission velocity of a pulse wave, including: a sensor portion for sensing heart sounds, and pulse wave signals upstream and downstream of a blood flow; an analog to digital conversion unit for converting the signals from the sensor portion from an analog to a digital form; a data processing unit for processing data received from the analog to digital conversion unit; and a display unit for displaying waveforms and numerical data received from the data processing unit. The data processing unit includes a first processor for detecting the first heart sound and generating a marker signal; second and third processors for transforming the received signals for a display thereof; a fourth processor responsive to signals from the first, second, and third processors and detecting the marker signal to thereby obtain predetermined data from the data received; a fifth processor for receiving signals from the second and third processors and temporarily storing the received signals; a sixth processor for receiving a signal from the fourth processor and measuring the transmission time of the pulse wave to thereby derive the transmission velocity of the pulse wave; and a seventh processor for receiving a signal from the sixth processor and transforming the received signal for a display thereof.

According to the present invention, there is also provided a method of measuring the transmission velocity of a pulse wave, including the steps of: receiving a heart sound signal, and pulse wave signals upstream and downstream of a blood flow; detecting a first sound from the received heart sound signal; obtaining a pulse wave signal upstream and a pulse wave signal downstream, based on a first sound of the received heart sound signal; detecting a comparison reference point based on the first sound of the received heart sound and the pulse wave signals upstream and downstream side; carrying out a waveform coincidence processing for the pulse wave signals upstream and downstream and, based on the waveform coincidence processing, measuring the transmission time of the pulse wave; and deriving the transmission velocity of the pulse wave using the measured transmission time of the pulse wave.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of an apparatus for measuring the transmission velocity of a pulse wave according to an embodiment of the present invention;

Fig. 2 illustrates the operation of an apparatus for measuring the transmission velocity of a pulse wave according to an embodiment of the present invention;

Fig. 3 shows an example of a flow chart of the processing carried out by the data processing unit of the apparatus for measuring the transmission velocity of a pulse wave;

Fig. 4 illustrates an example of the detection of the first of the heart sounds;

Fig. 5 illustrates an example of the detection of the transmission time of the pulse wave;

Fig. 6 illustrates an example of the processing of the waveform coincidence;

Fig. 7 shows examples of the actual detection of the first of the heart sounds;

Fig. 8 shows examples of the actual detection of the transmission velocity of the pulse wave; and

Fig. 9 shows examples of the actual detection of the transmission velocity of the pulse wave.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A schematic diagram of an apparatus for measuring the transmission velocity of a pulse wave according to an embodiment of the present invention is shown in Fig. 1 and the operation of this apparatus is illustrated in Fig. 2.

The apparatus shown in Fig. 1 is constituted by a sensor portion 1, an analog to digital conversion portion 2, a data processing portion 3, and a display portion 4. The sensor portion 1 includes a heart sound microphone 101, a pulse wave pickup 102 for the upstream side, a pulse wave pickup 103 for the downstream side, and pre-amplifiers 111, 112, and 113. The analog to digital conversion portion 2 includes filters 201, 202, and 203, sample and hold circuits 211, 212, and 213, analog to digital converters 221, 222, and 223, and interface circuits 231, 232, and 233. The data processing portion 3 includes a processor 31 for the first sound detection and the marker generation, a processor 32 for a transformation for a display thereof, a processor 33 for a transformation for a display thereof, a processor 34 for the marker detection and the predetermined data obtainment, a processor 35 as a buffer, a processor 36 for the transmission time measurement, and a processor 37 for a transformation for a display thereof. The display portion 4 includes waveform display units 41 and 43 and a numerical data display unit 42.

The measurement of the transmission velocity of the pulse wave over a range of about 5 cm to 8 cm of the carotid artery and the radial artery and

the finger tip portion is illustrated in Fig. 2. In the figure, the heart sound microphone 101, pulse wave pickup 102 for the upstream side of the blood flow, and pulse wave pickup 103 for the downstream side of the blood flow are mounted on a human body as an biological object. The signals from the microphone 101 and the pickups 102 and 103 are supplied to pre-amplifiers 111, 112, and 113, and the signals from the preamplifiers 111, 112, and 113 are supplied to the analog to digital conversion portion 2. The signals from the interface circuits 23 in the analog to digital conversion portion 2 are supplied to the data processing portion 3, and the signals from the processor 35, transmission time measurement unit 36, and transmission for display unit 37 in the data processing portion 3 are supplied to the display portion 4.

A photo-electric sensor having a peak sensitivity wavelength at infra-red range, or a scattered light detection type sensor with an infra-red light emitting diode, or the like, may be used for the pulse wave sensor. Also, a sensor in which minor variations of the skin surface are absorbed by a rubber balloon and a change in the pressure in the rubber balloon is detected by a semiconductor pressure sensor, or a piezoelectric film sensor, or the like, may be used, for the pulse wave sensor.

The conversion process in the analog to digital conversion portion 2 is such that a 16 bit resolution is provided for plus/minus 10 volts, and a sampling rate of 50 kHz is provided.

In the data processing portion 3, each of the processors 31 to 37 may be a functional element called "Transputer". The "Transputer" may be the T800, 20 MHz type.

In the processor 31, the signal from the interface circuit 231 is received, the first of the heart sounds is detected, the marker signal of 10 volts or the like is superposed on the received signal during a time of several tens of msec, and the produced signal is transmitted as a unit of 1000 data to the processor 34.

In the processor 32, the signal from the interface circuit 232 is received, the received data is transformed for a real time display of the waveform of the pulse wave at the upstream side, the transformed data is transmitted to the processor 35, and the received data is transmitted as a unit of 1000 data to the processor 34.

In the processor 33, the signal from interface circuit 233 is received, the received data is transformed for a real time display of the waveform of the pulse wave at the downstream side, the transformed data is transmitted to the processor 35, and the received data is transmitted as a unit of 1000 data to the processor 34.

In the processor 34, the heart sound and two pulse wave signals are received, the marker signal of the heart sound signal is first detected, data of 25000 points from the detection of the marker signal is then picked up, the lowest points, the highest points, and 1/5 points of the pulse wave amplitudes, and the time difference to between the 1/5 points, are detected for the two pulse waves based on the picked-up 25000 point data, the data of 25000 points is normalized to assign the values of minus 30000 and plus 30000 for the lowest and the highest amplitudes of the pulse waves, so that the direct current components of the pulse waves are eliminated, and the produced data is transmitted to the processor 36. The 25000 point data corresponds to data of 500 msec for 50 kHz.

In the processor 35, the buffering of the data of the heart sound and the two pulse waves received from processors 32 and 33 is carried out, and after the buffering, the data is transmitted to the waveform display 41 in the display portion 4.

In the processor 36, the waveform coincidence processing by the least square method is carried out based on the 1/5 points, and the time difference between 1/5 points with regard to the region of the forward 5000 point data (corresponding to 100 msec), to obtain the transmission time T_1 of the pulse wave (the first time waveform coincidence processing). The waveform coincidence processing by the least square method is carried out based on the obtained transmission time T_1, to obtain the transmission time T_2 of the pulse wave (the second time waveform coincidence processing). The waveform coincidence processing by the least square method is carried out based on the obtained transmission time T_2, to obtain the transmission time T_3 of the pulse wave (the third time waveform coincidence processing). The transmission velocity of the pulse wave is calculated based on the obtained transmission time T_3 and distance L of the measurement of the pulse wave, and the data of the calculated transmission velocity is transmitted to the numerical data display unit 42 in the display portion 4. The data of the lowest and the highest points and 1/5 points of the amplitudes of the pulse waves and the data region information to which the least square method has been applied, and 25000 point data of the heart sounds and the pulse waves, are transmitted to the processor 37.

In the processor 35, the buffering of the heart sound signal and the two pulse wave signals from processors 31, 32, and 33 is carried out, and after the buffering, the signals are transmitted to the waveform display unit 41 in the display portion 4.

In the processor 37, the data received from the processor 36 is transformed into data for display, whereby it is determined whether or not the processing by the processors has been regularly achieved, is made as a graphic display. The trans-

formed data for display is transmitted to the waveform display unit 43 in the display portion 4.

An example of the flow chart of the processing by the data processing portion of the apparatus for measuring transmission velocity of a pulse wave is shown in Fig. 3.

The first of the heart sounds is detected and the marker signal is superposed in step S1; the data of the two pulse wave signals is derived from the marker signal in step S2; the lowest point, the highest point, and 1/5 point of amplitude of the pulse wave, and the time difference between 1/5 points are detected in step S3; the waveform coincidence processing of the data by the least square method is carried out and the transmission time of the pulse wave is detected in step S4; the pulse wave velocity is detected based on the detected transmission time in step S5; and the indication of the detected pulse wave velocity is output in step S6.

An example of the detection of the first of the heart sounds is illustrated in Fig. 4. With regard to the first and the second heart sounds of a human being, the amplitude of the first sound is detected as a large amplitude, and subsequently, the second sound is detected as a large amplitude. By using a threshold value E, several points of the first sound group and several points of the second sound group are detected. To detect the first detected point as the first or second point, an inhibition time (It) is provided which is several tens of msec from the relevant detection point, to exclude the remaining points. It is assumed that the first sound is the sound of the closing of the mitral valve in the heart, i.e., the sound of the closing of the valve simultaneously with the charging of the blood from the left atrium into the left ventricle, and the second sound is the sound of the closing the aortic valve when the blood is delivered from the left ventricle into the aorta.

If the time interval T_n, between the two successive sounds is greater than T_{n-1} between the immediately preceding two successive sounds, i.e., $T_n > T_{n-1}$, the detected point is determined as the first sound. Conversely, if $T_{n-1} > T_n$, the detected point is determined to be the second sound. This is because the interval between the first sound and the second sound is less than the interval between the second sound and the first sound.

The marker signal, which is a pulse signal having a width of several tens of msec, from the detection point of the first sound is superposed on the original signal. The marker signal is used for checking the waveform on the real time monitor and for information necessary to the subsequent processes. The measurement of time is carried out by a timer in the processors.

To measure the transmission time of the pulse wave, first the 1/5 point and the transmission time of the pulse wave between 1/5 points are detected, and, then the waveform coincidence processes by the least square method are carried out.

An example of the detection of the transmission time of the pulse wave is illustrated in Fig. 5. The marker signal superposed on the first sound of the heart sound is detected, and the data of 500 msec, i.e. data of 25000 points, from the detection of the marker signal is derived. In this region, the lowest points (Min (1), Min (2)) and the highest points (Max (1), Max (2)) of the amplitudes of the two pulse waves are detected, and the point t_{e1} of the 1/5 of the amplitude at the upstream side based on the relationship

$$(MAX(1) - MIN(1))/(5 + MIN(1))$$

and the point t_{e2} of the 1/5 of the amplitude at the downstream side based on a similar relationship are detected. The pulse wave transmission time T_o based on the detection of the 1/5 point is obtained from the time difference $t_{e2} - t_{e1}$.

An example of the processing of the waveform coincidence by the least square method is illustrated in Fig. 6. It is assumed that t_{e1} is the 1/5 point of the amplitude of the pulse wave at the upstream side, t_{e2} isthe 1/5 point of the amplitude of the pulse wave at the downstream side, T_o is the estimated value of the transmission time of the pulse wave based on the detection of the 1/5 point, T_k is the estimated value of the transmission time of the pulse wave, ds is the interval of the analysis sampling, di is the time of the analytical chopping of time, and dw is the range of the time of the analysis. Also, it is assumed that n = 1, 2, 3, ... 2 dw/di, m = 1, 2, 3, ..., k = 1, 2, 3, ..., $T_o = t_{e2} - t_{e1}$, $t_{e1} - t_{s1}$ = 100 msec, and $t_{e2} - t_{s2}$ = 100 msec.

The sum $E_r(n)$ of the squares of the differences between the amplitudes of the pulse waves for the band of the data is calculated, and the transmission time T_R of the pulse wave with regard to the minimum "n" for $E_r(n)$ is derived. It is assumed that:

$$dt = T_{k1} - dw \quad (1)$$

The sum $E_r(n)$ of the squares is given according to the following equation:

$$E_r(n) = \Sigma(P_1(t_{s2} - dt + di \cdot n + ds \cdot m) - P_2(t_{s2} + ds \cdot m)^2$$

where the summation Σ is for from m = 1 to

$$(T_{e2} - T_{s2})/ds \quad (2)$$

The value of T_k is given according to the following

equation:

$$T_k = dt + di \cdot n \quad (3)$$

The operation of the waveform coincidence processing by the least square method is carried out according to the above indicated equations.

First, by using T_0, the transmission time T_1 of the pulse wave for the first time is obtained under the condition that ds = 50, di = 100, and dw = 400. In this case, 50 corresponds to 1 msec, 100 to 2 msec, and 400 to 8 msec.

Next, by using T_1, the transmission time T_2 of the pulse wave for the second time is obtained under the condition that ds = 10, di = 20, and dw = 50. In this case, 10 corresponds to 200 µsec, 20 to 400 µsec, and 50 to 1 msec.

Finally, by using T_2, the transmission time T_3 of the pulse wave for the third time is obtained under the condition that ds = 5, di = 2, and dw = 20. In this case, 5 corresponds to 100 µsec, 2 to 40 µsec, and 20 to 400 µsec.

By using the thus obtained transmission time T_3 of the pulse wave, a calculation with the distance L in meters is carried out, to obtain the transmission velocity $V = L/T_3$ of the pulse wave in meters/sec.

Examples of the detection of the first of the heart sounds are illustrated in Fig. 7. The upper waveform shows the case where the gain of the pre-amplifier of the sensor portion is 20, the gain of the middle waveform is 50, and the gain of the lower waveform is 100. It is acknowledged that marker signals are superposed immediately after the detection of the first of the heart sounds, and the first sound is successfully detected.

Examples of the detection of the transmission velocity of the pulse wave are illustrated in Fig. 8. The pulse wave velocity is detected for pulse waves wherein a noise of the sinusoidal waveform type is superposed on pulse waves. In the detection, a simulation signal generated from a simulation signal generator and a noise signal generated from a noise signal generator are used.

With the integration of the number of heart beats along the abscissa, first the number of the heart beat, second the pulse wave velocity by the 1/5 point detection, and third, the pulse wave velocity by the least square method detection are illustrated. It is acknowledged that the detected error for the high frequency components of the noise is less in the case of the least square method than in the case of the 1/5 point method.

Examples of the detection of the transmission velocity of the pulse wave are illustrated in Fig. 9. The pulse wave velocity is detected for pulse waves wherein a pseudo random noise is superposed on the pulse waves. A signal having the sinusoidal waveform of the peak-to-peak 100 milli volts from a noise generator is superposed on the pulse wave signal at the downstream side. The measurement is carried out by changing the frequency, the range of the ultimate noise component is limited to 40 Hz by a low pass filter. It is acknowledged that the precision of measurement of the pulse wave velocity is higher in the case of the least square method than in the case of the 1/5 point method.

Claims

1. An apparatus for measuring a transmission velocity of a pulse wave comprising:
   a sensor portion (1) for sensing heart sounds, and pulse wave signals at upstream and downstream sides of a blood flow;
   an analog to digital conversion portion (2) for converting signals from said sensor portion (1) from analog to digital form;
   a data processing portion (3) for processing data received from said analog to digital conversion portion (2) and a display portion (4) for displaying waveforms and numerical data received from said data processing portion;
   said data processing portion (3) comprising:
   a first processor (31) for detecting a first heart sound and generating a marker signal;
   second and third processors (32,33) for transforming the signals received for display;
   a fourth processor (34) responsive to signals from the first, second, and third processors (31,32,33) for detecting the marker signal and obtaining predetermined data from the data received;
   a fifth processor (35) for receiving signals from the second and third processors (32,33) and temporarily storing the received signals;
   a sixth processor (36) for receiving signals from the fourth processor und measuring the transmission time of the pulse wave to derive the transmission velocity of the pulse wave; and
   a seventh processor (37) for receiving signals from the sixth processor (36) and transforming the received signals for a display thereof.

2. An apparatus according to claim 1, wherein said sensor portion (1) comprises a heart sound microphone (101); a pulse wave pick-up (102) at the upstream side of the blood flow, a pulse wave pick-up (103) at the downstream side of the blood flow, and pre-amplifiers (111,112,113).

3. An apparatus according to claim 1, wherein said analog to digital conversion portion com-

prises filters (201-203), sample und hold circuits (211-213), analog to digital converters, and interface circuits (231-233).

4. An apparatus according to claim 1, wherein said display portion (4) comprises waveform display devices (41,42,43) and a numerial data display device.

5. A method of measuring a transmission velocity of a pulse wave, comprising the steps of:
receiving heart sound signals, and pulse wave signals at the upstream and downstream side of a blood flow;
detecting a first sound from the received heart sound signals;
obtaining a pulse wave signal at the upstream side and a pulse wave signal at the downstream side based on a first of the received heart sound signals;
detecting a comparison reference point based on the first of the received heart sound signals and the pulse wave signals at the upstream side and the downstream side;
carrying out a waveform coincidence processing for the pulse wave signals at the upstream side and the downstream side and, based on the waveform coincidence processing, measuring the transmission time of the pulse wave; and deriving the transmission velocity of the pulse wave using the measured transmission time of the pulse wave.

6. A method according to claim 5, wherein, in the detection of the first of the heart sound signals, a marker signal is superposed on the detected first heart sound signal, and, in the detection of the comparison reference point, the marker signal is detected and the pulse wave signal at the upstream side and the pulse wave signal at the downstram side are obtained.

7. A method according claim 6, wherein, in the obtaining of the pulse wave signal at the upstream side and the pulse wave signal at the downstream side, data within a predetermined length of time from the detection of the marker signal is acquired, the lowest points and the highest points of amplitudes of the pulse waves at the upstream and downstream sides are obtained, and the comparison reference points are derived from the acquired data, and the time difference between the derived comparison reference points is obtained.

8. A method according to claim 5, wherein, in the measurement of the transmission time, a waveform coincidence processing by the least square method for predetermined ranges from the comparison reference points is carried out based on the comparison reference points and the time difference therebetween, and, based on the waveform coincidence processing, the transmission time of the pulse wave is measured.

9. A method according to claim 5, wherein the data processing in the sequence of the steps is carried out by using a parallel processing system for digital data, and accordingly, a real time processing in synchronization with the heart beat is achieved.

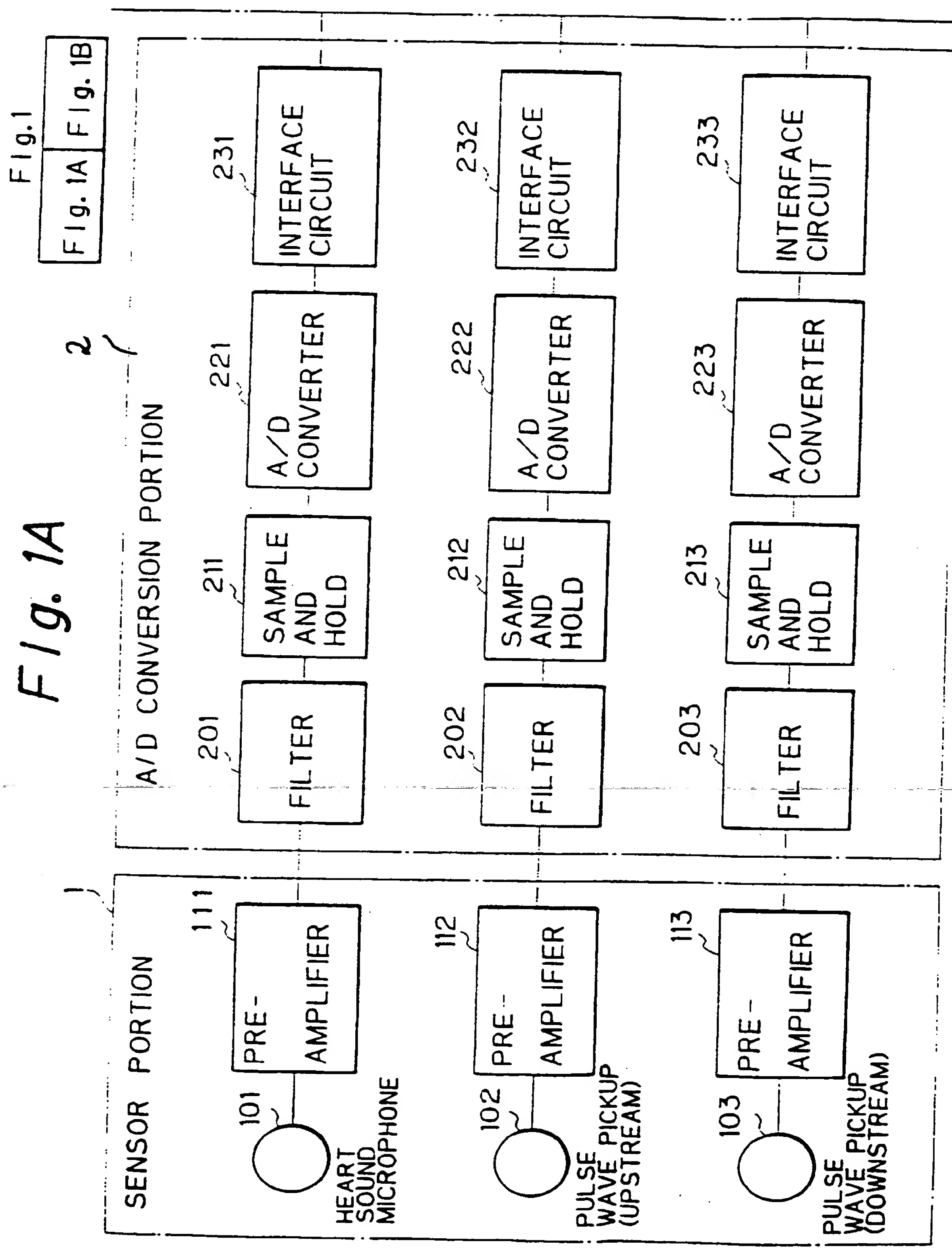


Fig.1
Fig. 1A
Fig. 1B
SENSOR PORTION
1
101
HEART SOUND MICROPHONE
102
PULSE WAVE PICKUP (UPSTREAM)
103
PULSE WAVE PICKUP (DOWNSTREAM)
111
112
113
PRE-AMPLIFIER
PRE-AMPLIFIER
PRE-AMPLIFIER
A/D CONVERSION PORTION
2
201
202
203
FILTER
FILTER
FILTER
211
212
213
SAMPLE AND HOLD
SAMPLE AND HOLD
SAMPLE AND HOLD
221
222
223
A/D CONVERTER
A/D CONVERTER
A/D CONVERTER
231
232
233
INTERFACE CIRCUIT
INTERFACE CIRCUIT
INTERFACE CIRCUIT

Fig. 1A

Fig. 1B

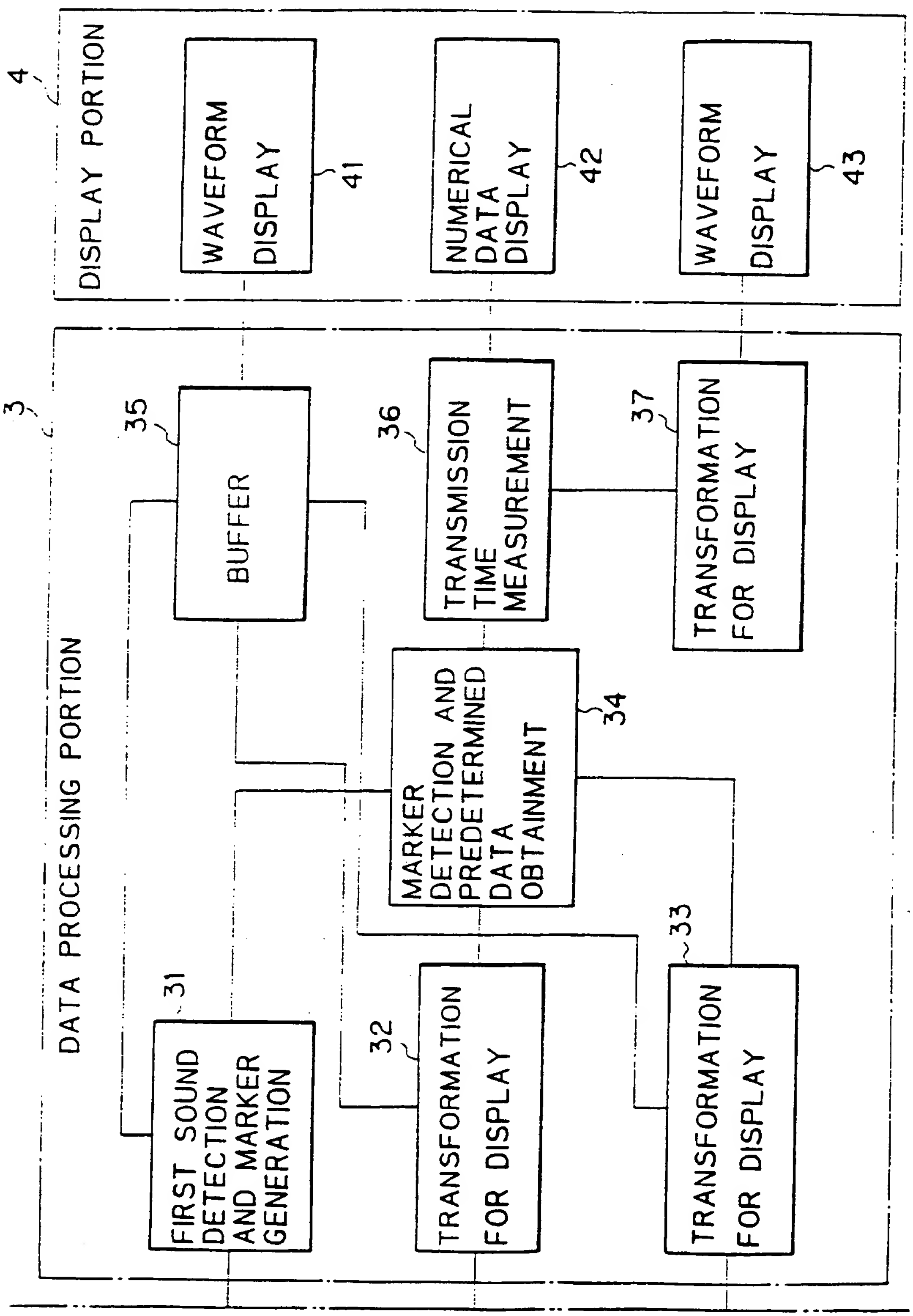

DISPLAY PORTION
4
WAVEFORM DISPLAY
41
NUMERICAL DATA DISPLAY
42
WAVEFORM DISPLAY
43
DATA PROCESSING PORTION
3
BUFFER
35
TRANSMISSION TIME MEASUREMENT
36
TRANSFORMATION FOR DISPLAY
37
MARKER DETECTION AND PREDETERMINED DATA OBTAINMENT
34
FIRST SOUND DETECTION AND MARKER GENERATION
31
TRANSFORMATION FOR DISPLAY
32
TRANSFORMATION FOR DISPLAY
33

Fig. 2

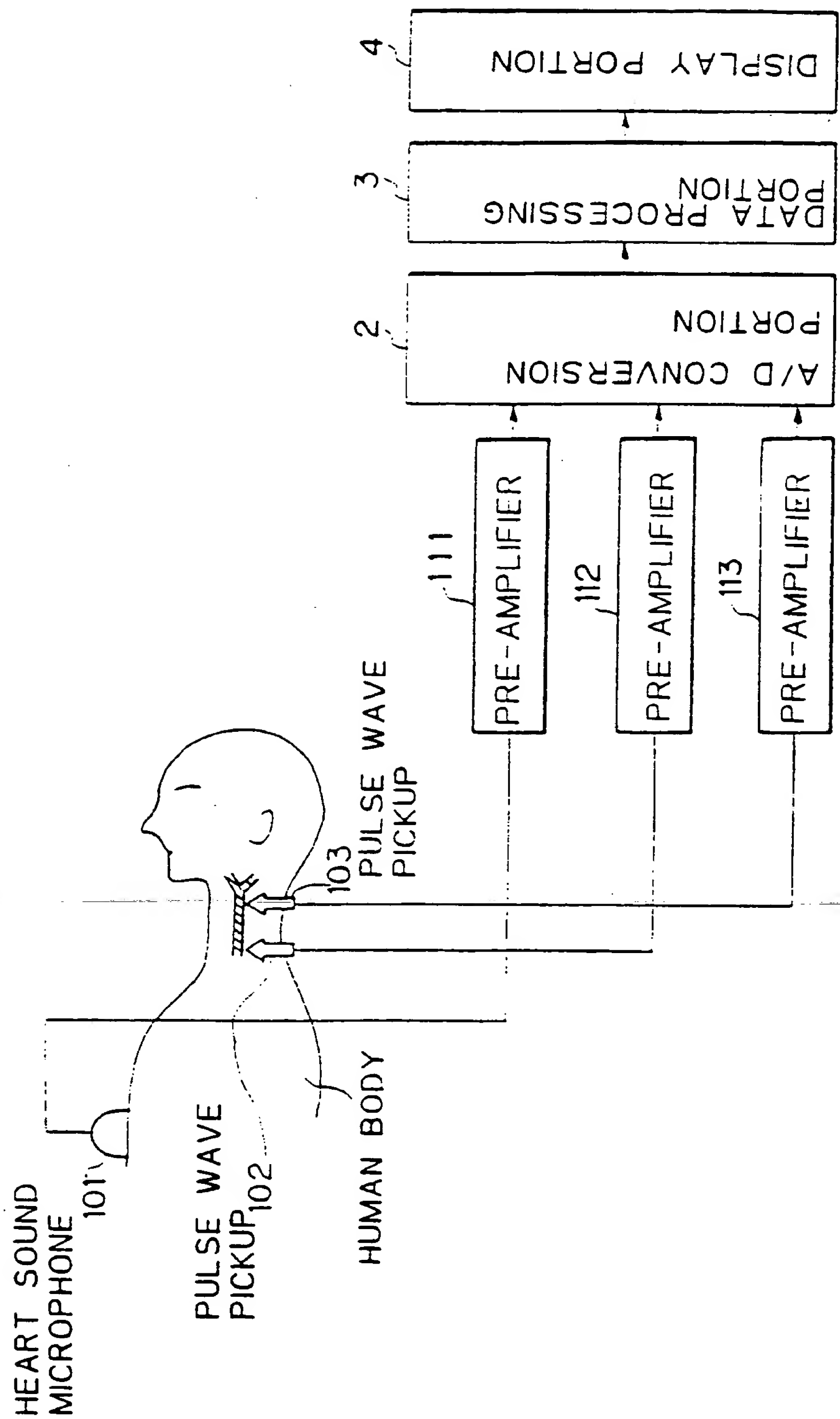

DISPLAY PORTION
4
DATA PROCESSING PORTION
3
A/D CONVERSION PORTION
2
PRE-AMPLIFIER
111
PRE-AMPLIFIER
112
PRE-AMPLIFIER
113
PULSE WAVE PICKUP
103
HEART SOUND MICROPHONE
101
PULSE WAVE PICKUP
102
HUMAN BODY

Fig. 3

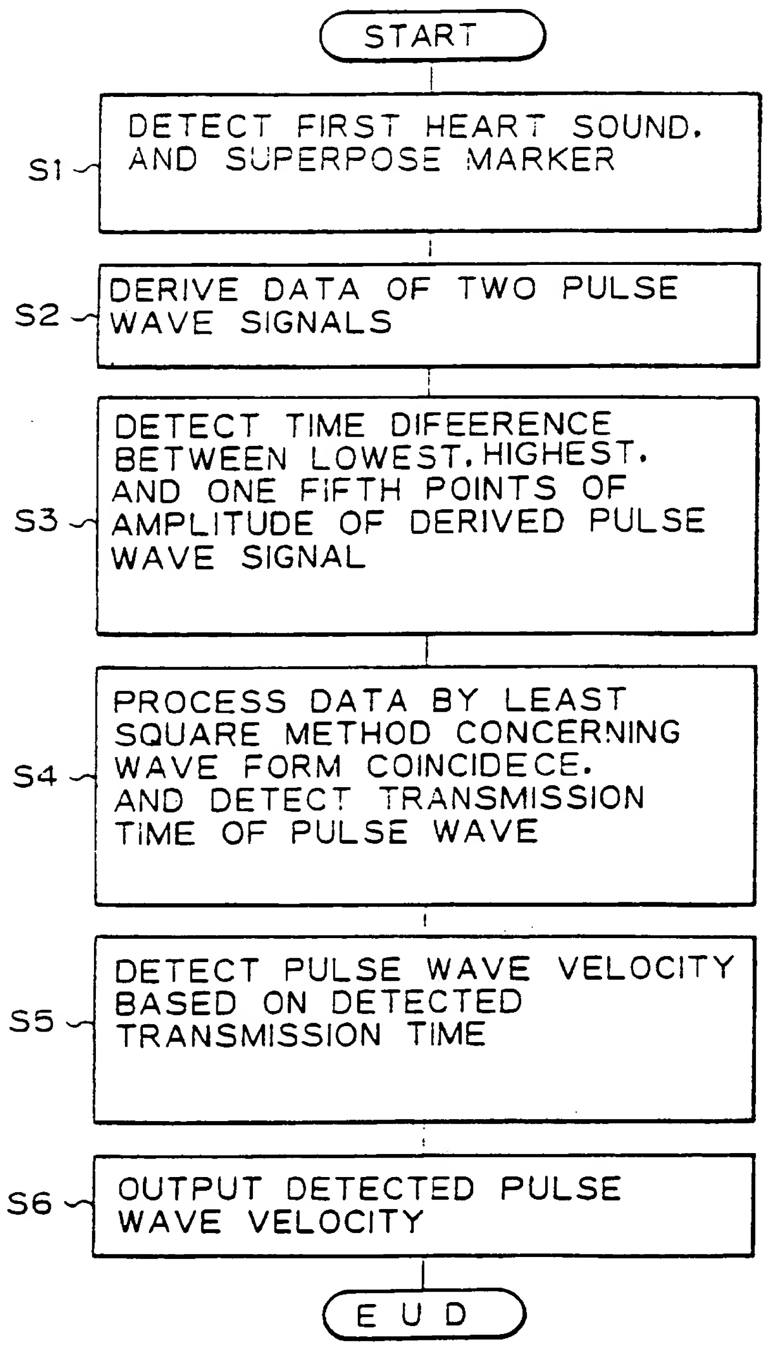

START
S1
DETECT FIRST HEART SOUND. AND SUPERPOSE MARKER
S2
DERIVE DATA OF TWO PULSE WAVE SIGNALS
S3
DETECT TIME DIFEERENCE BETWEEN LOWEST. HIGHEST. AND ONE FIFTH POINTS OF AMPLITUDE OF DERIVED PULSE WAVE SIGNAL
S4
PROCESS DATA BY LEAST SQUARE METHOD CONCERNING WAVE FORM COINCIDECE. AND DETECT TRANSMISSION TIME OF PULSE WAVE
S5
DETECT PULSE WAVE VELOCITY BASED ON DETECTED TRANSMISSION TIME
S6
OUTPUT DETECTED PULSE WAVE VELOCITY
E U D

Fig. 4

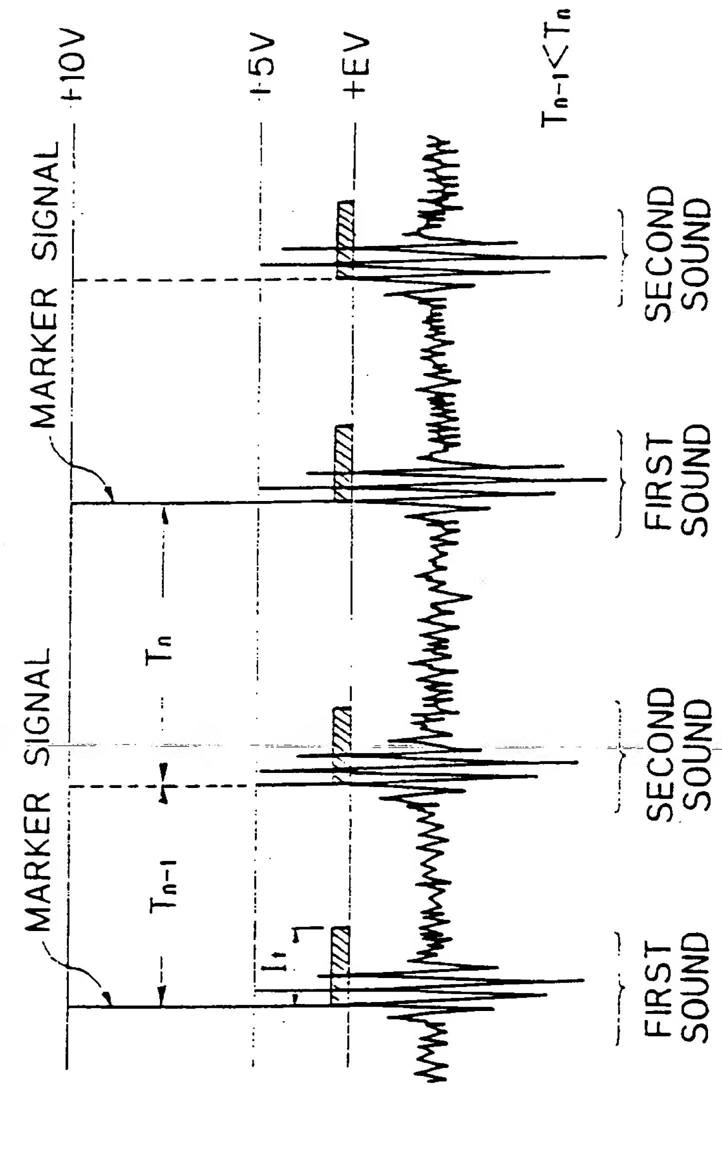

MARKER SIGNAL
MARKER SIGNAL
+10V
+5V
+EV
$T_{n-1} < T_n$
T_n
T_{n-1}
T_1
FIRST SOUND
SECOND SOUND
FIRST SOUND
SECOND SOUND

Fig. 5

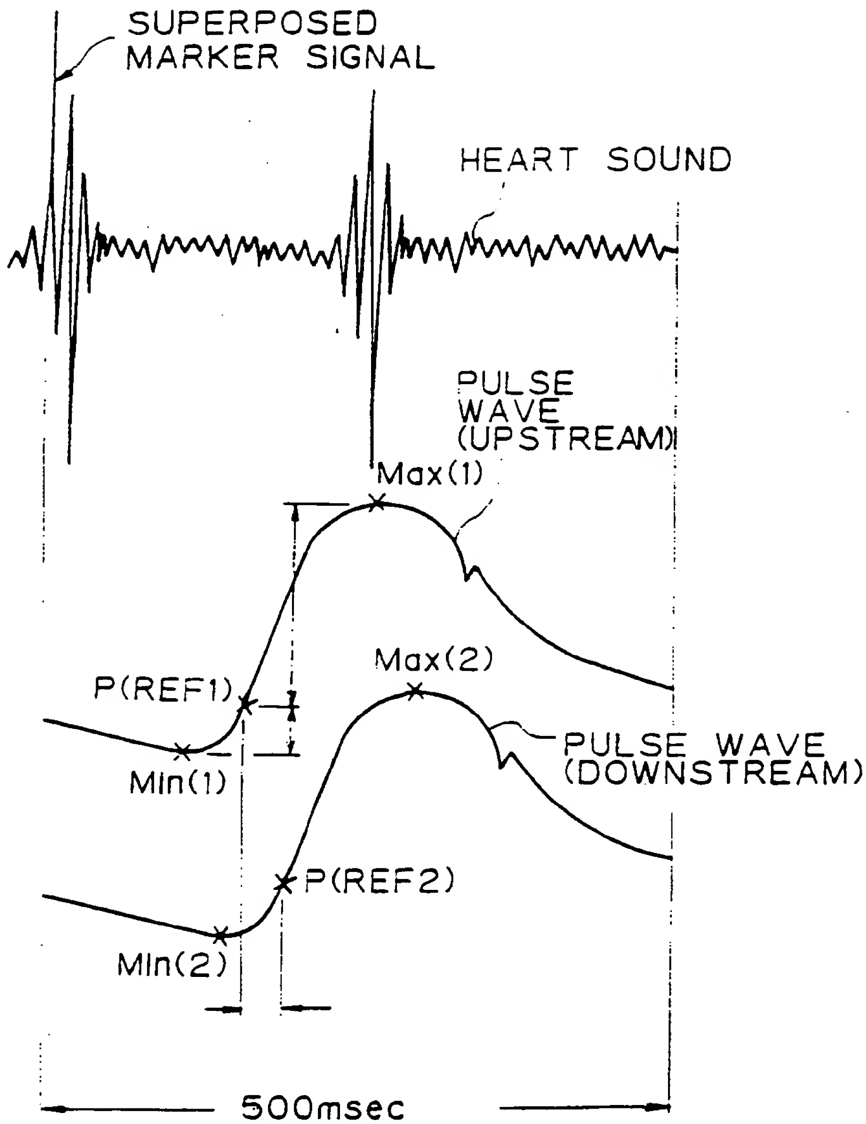

SUPERPOSED MARKER SIGNAL
HEART SOUND
PULSE WAVE (UPSTREAM)
Max(1)
P(REF1)
Min(1)
Max(2)
PULSE WAVE (DOWNSTREAM)
P(REF2)
Min(2)
500msec

Fig. 6

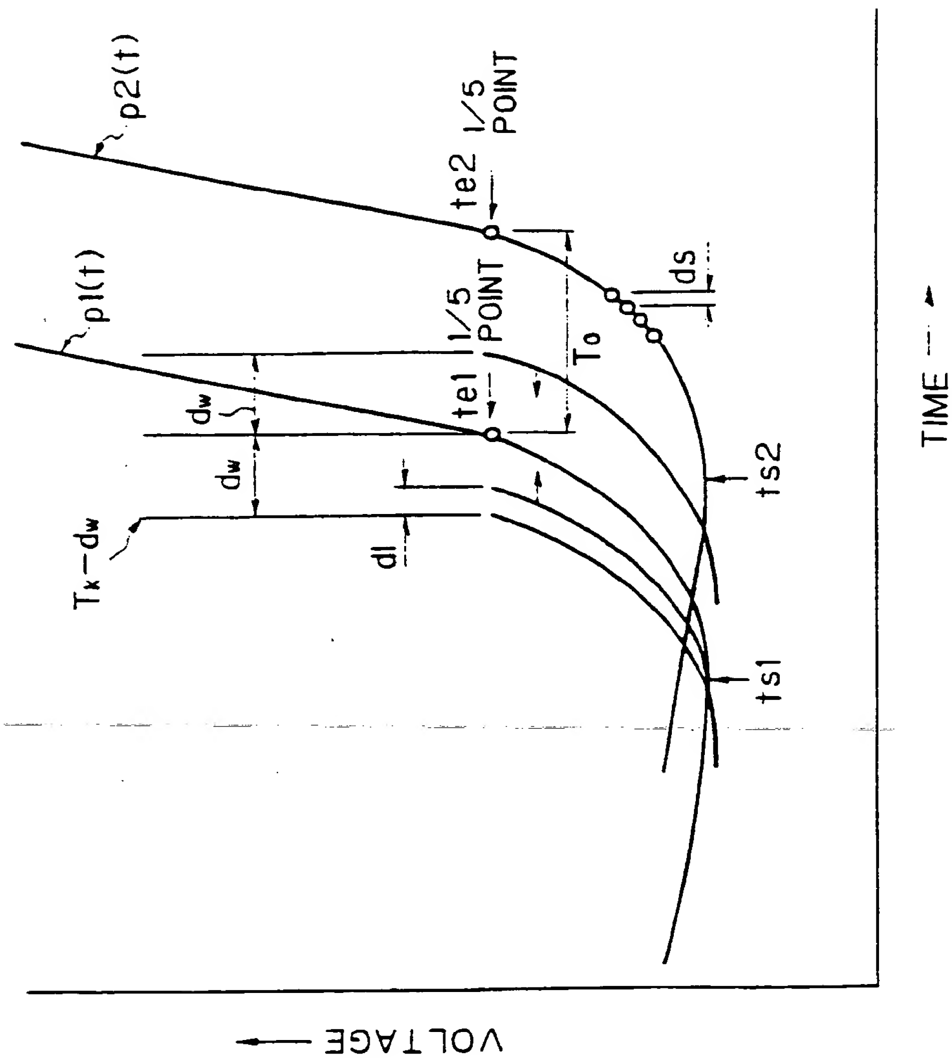

p2(t)
p1(t)
te2
1/5 POINT
te1
1/5 POINT
To
ds
dw
dw
dl
Tk−dw
ts1
ts2
TIME
VOLTAGE

Fig. 7

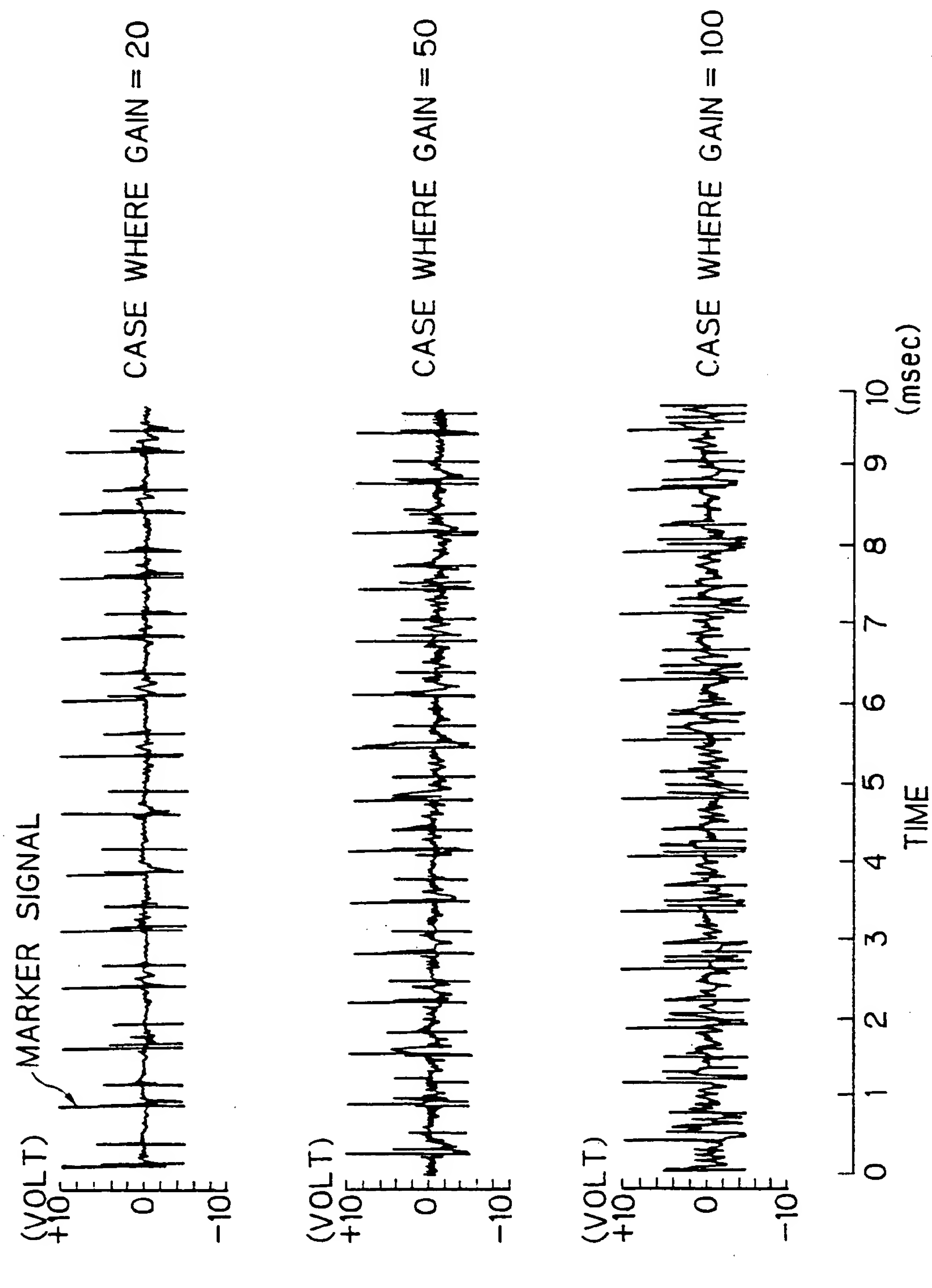

MARKER SIGNAL
(VOLT)
+10
0
-10
CASE WHERE GAIN = 20
CASE WHERE GAIN = 50
CASE WHERE GAIN = 100
0
1
2
3
4
5
6
7
8
9
10
(msec)
TIME

Fig. 8

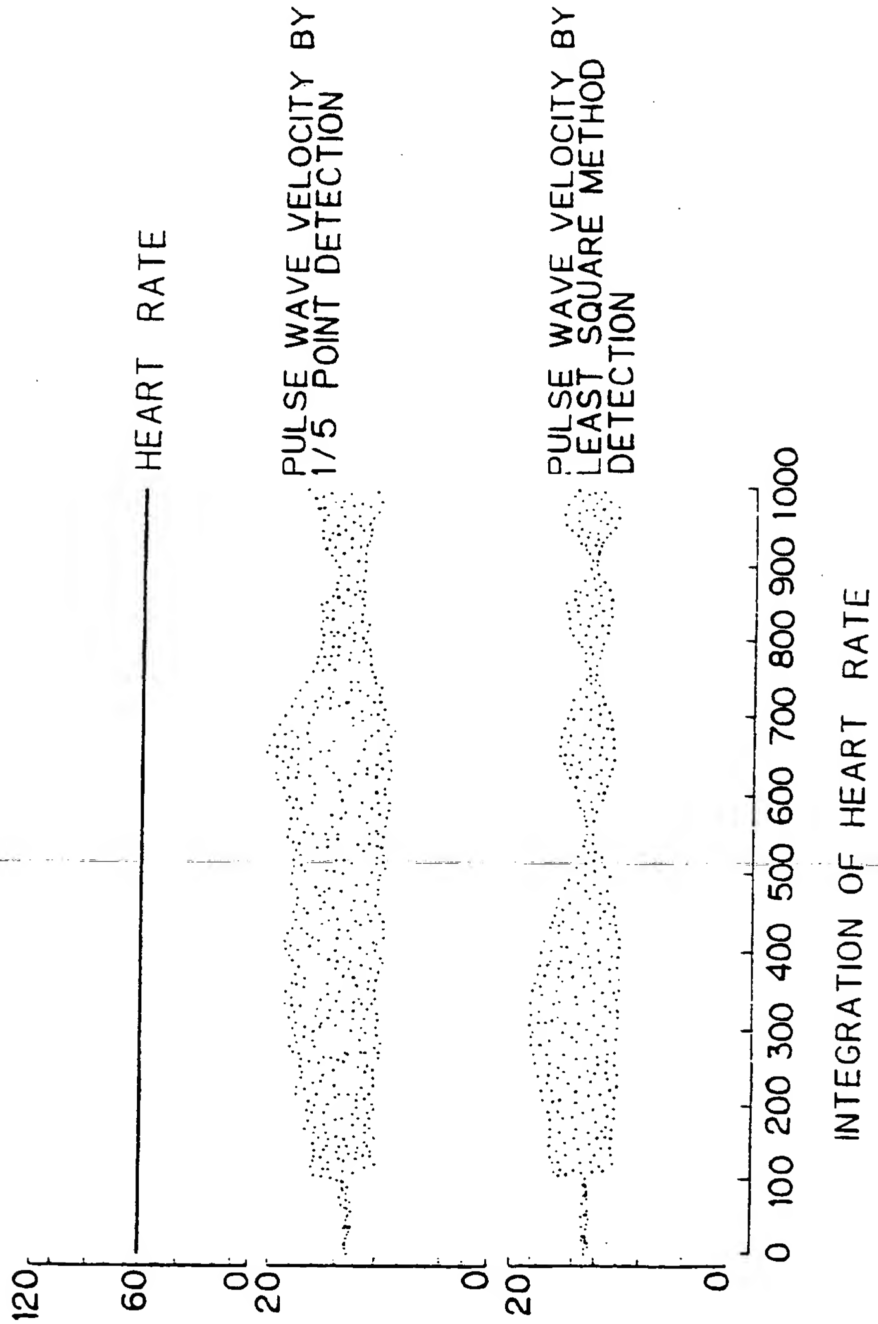
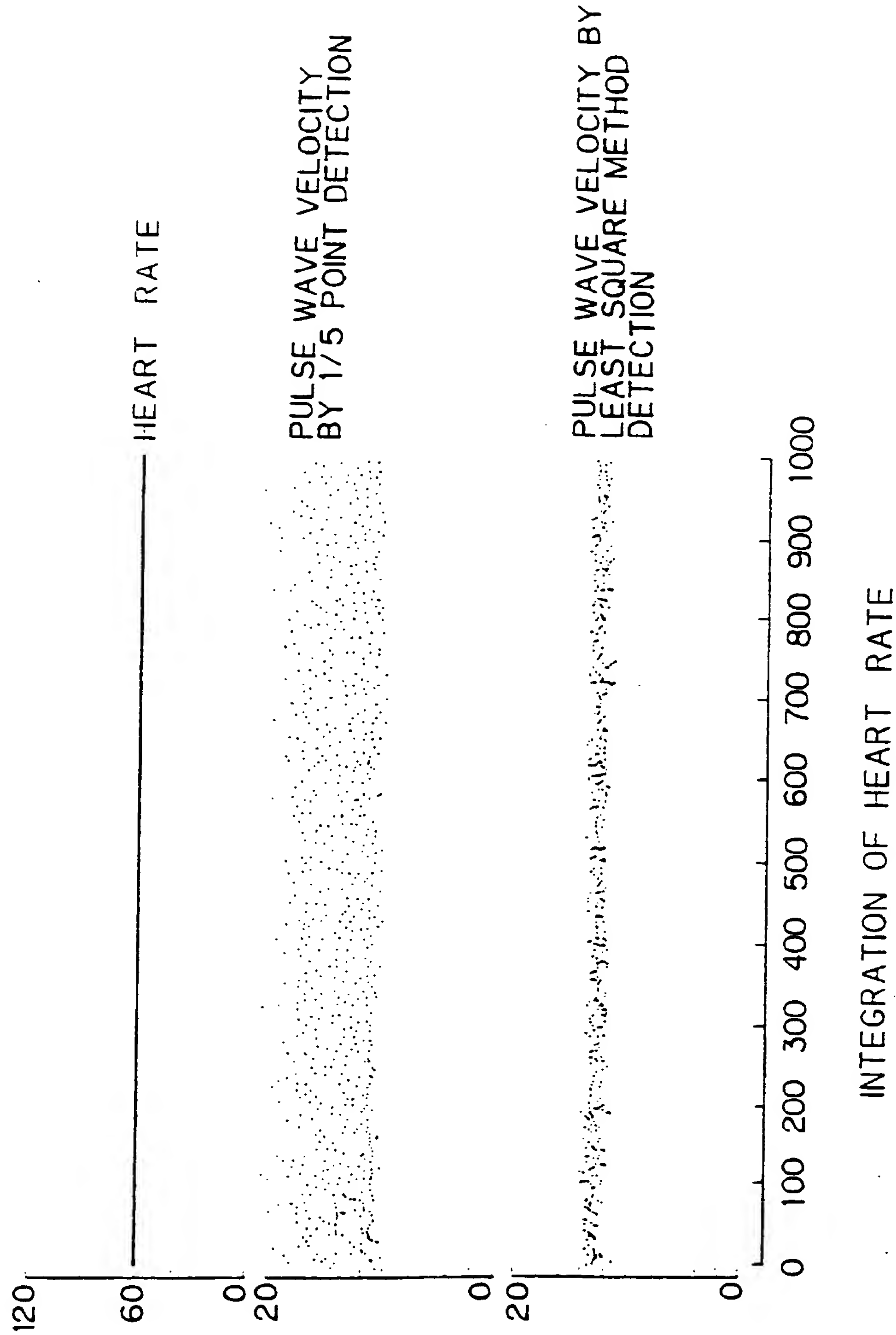

HEART RATE
PULSE WAVE VELOCITY BY 1/5 POINT DETECTION
PULSE WAVE VELOCITY BY LEAST SQUARE METHOD DETECTION
120
60
0
20
0
20
0
0 100 200 300 400 500 600 700 800 900 1000
INTEGRATION OF HEART RATE

Fig. 9


HEART RATE
PULSE WAVE VELOCITY BY 1/5 POINT DETECTION
PULSE WAVE VELOCITY BY LEAST SQUARE METHOD DETECTION
120
60
0
20
0
20
0
0
100
200
300
400
500
600
700
800
900
1000
INTEGRATION OF HEART RATE

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 1414

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-3 132 643 (J.N.BAUM ET AL) * column 2, line 24 - column 3, line 58; figure 1 *	1-4	A61B5/0285
A	US-A-4 245 648 (G.A.TRIMMER ET AL) * column 1, line 58 - column 2, line 4 * * column 7, line 19 - column 8, line 3; figures 1-7 *	1-4	
A	FR-A-2 281 093 (FISONS LIMITED) * page 1, line 8 - page 4, line 9; figure 1 *	1,2	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			A61B G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	21 APRIL 1992	WEIHS J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document